RAPID TRANSIT IN NEW YORK.

OPEN LETTER

TO

HON. ABRAM S. HEWITT,

ON THE VARIOUS MOTIVE POWER SYSTEMS PROPOSED FOR THE OPERATION OF RAPID TRANSIT LINES IN THE CITY OF NEW YORK.

ALSO,

A REPRINT OF DISCUSSION IN THE "STREET RAILWAY GAZETTE," AND "STREET RAILWAY REVIEW," OF CHICAGO, ON THE RELATIVE COST OF INSTALLATION AND OPERATION OF LINES OPERATED BY STEAM, ELECTRICITY, AND COMPRESSED AIR.

BY HERMAN HAUPT, C. E.,

WASHINGTON, D. C.

BYRON S. ADAMS, PRINTER.

Rapid Transit in New York.

An Open Letter to Hon. Abram S. Hewitt.

Sir :

My attention has been directed to an article on rapid transit in New York published in the "Herald" of November 18th, which professes to give the results of interviews with prominent citizens as to the best power to be used in the operation of the proposed rapid-transit lines in your city.

The great interest that you have taken in this question, your familiarity with proposed plans of operative, and with the physical laws upon which their success depends, has induced me to address to you this communication in which an attempt will be made to show the utter impracticability of some of the suggestions that have been made, and the relative economy and efficiency of such other systems as may be regarded as practicable, although not equally meritorious.

Hot water, carbonic acid, ammonia, gas, and storage-battery, have all been proposed as sources of motive power, but none of them are available as will be briefly explained.

The remaining competitors for favor, must be steam, cable, electricity, and compressed air.

This paper must necessarily be brief. I propose simply to state conclusions. To enunciate the thermodynamic and other physical laws involved in the discussion of these subjects, and demonstrate the soundness of the conclusions reached would require a volume. Those upon whom the decision must rest, will, if wise, employ disinterested and competent experts to investigate the merits of each and every proposed system, and report facts, not theories, or con-

jectures. Much information in regard to motors is given in a recent publication by Henry Cary Baird of Philadelphia, of which you have a copy, but an abstract of results can be here given, having reference to the suggestions of the "Herald" article above referred to.

Hot Water Motors.

Water possesses greater capacity for heat than any other substance, in consequence of which attempts have been made to store up heat for motive power at very high temperature, and allow the water to be expanded into steam by the reduction of pressure in the motor cylinders.

It is simply astonishing that nearly all who have figured upon the results of this application have failed to recognize the fact, that in passing from water into steam nearly one thousand units of heat become latent, and this abstraction of heat so rapidly reduces the temperature of the remaining water that only a comparatively small portion can be converted into steam before the temperature and pressure are so far reduced as to render it impossible to operate the motor.

In a recent example, submitted to the writer, it was calculated that if 600 pounds of water were heated to a high temperature of 480° in a strong tank, under a pressure of 600 pounds per square inch, only 140 pounds could be utilized until the pressure would fall to 60 pounds, and the quantity of coal required to raise the water to a temperature of 480° would be much more than would be required to produce the steam direct as in a locomotive.

This hot water idea is by no means new. A number of hot water or fireless locomotives were constructed in New Orleans twenty-five years ago by a company of which General Beauregard was president, and run between that city and Lake Pontchartrain, but were abandoned after long trial, and horse-power substituted.

In a recent discussion of the hot-water engine in an engineering society, none of the members who participated therein appear to have recognized the fact of the great loss of sensible heat and power by the conversion of water into steam.

Unless a fire-box be added to generate steam by the aid of fuel a hot-water engine can have only a very short run, but if fuel is used it becomes a very poor steam-locomotive.

Carbonic Acid Motors.

The attempt to use these motors is an illustration of the extreme gullibility of capitalists, who have but limited knowledge of physical laws and are imposed upon by confident and persistent inventors. With the exception of the Keely motor, no more visionary scheme than this has been presented to a credulous public.

The claim that a pressure of 5,000 pounds per square inch can be produced by the use of carbonic acid is fascinating to the ignorant. It is true that 5,000 pounds and more can be produced by heating carbonic acid in tubes or close and strong tanks, but such pressure cannot possibly be utilized for propulsion. The fact has been fully demonstrated by the tests of Col. Beaumont in England, and by Hardie in this country, that very high pressures cannot be used to any advantage expansively in motor cylinders, and that when air was used in compound engines at 1,000 pounds pressure, and also at 200 pounds, the same weight of air would run the motor to the same distance. The most economical pressure to be used in the cylinder has been found to be about 125 to 150 pounds.

If cold air at high pressure, which does not condense, cannot be economically used in the motor cylinders, certainly no other elastic fluid which derives its pressure from the application of heat can be employed with better prospect of suc-

cess. Steam could be superheated as well as carbonic acid to almost any temperature and pressure, and so also could air, but a high heat would burn out the lubricants and destroy the cylinders; there would be great loss from radiation and the expansion in the cylinders would result in such rapid cooling as to very quickly absorb the pressure secured by the application of heat.

If carbonic acid could be furnished for nothing it would not pay to use it, but it is expensive. If exhausted after doing its work, there would be great waste, and if attempted to be condensed, the apparatus would be too complicated for a motor.

Carbonic acid is a liquid at a temperature of 32 degrees, under a pressure of 38½ atmospheres, or 577 pounds, consequently it is not possible to secure pressures of 5,000 to 10,000 pounds, except by the application of heat, and even if such pressures could be secured, as can be done with air, without high temperature, such pressure would be absolutely of no practical use and could not be applied to any motor. Pressures secured by the application of heat are lost in cooling. Air, on the contrary, does not condense and retains its pressure until used.

Ammonia Motors.

Ammonia possesses very remarkable properties. At ordinary temperature it is a permanent gas giving a pressure of 100 pounds to the square inch at 60° Fahrenheit, while water to give an equivalent pressure must be heated to 325°.

Ammonia liquefies at ordinary temperature under a pressure of 17 atmosphere or 250 pounds per square inch, and by cold alone at 40° below zero.

At the temperature of freezing, water will absorb more than a thousand times its volume.

The remarkable properties of ammonia and the low temperature at which a high pressure can be secured, indicate the probability and almost certainty of a wide and profitable field for ammonia engines for stationary, and probably also for marine purposes. Theory confirms the claim of a saving of 50 per cent. in fuel in stationary engines, and direct tests with the Campbell engine have proven that this claim is well founded, but as the ammonia, after performing its work in the cylinders, must be absorbed by cold water and redistilled, and as distilling apparatus cannot be applied with advantage to a traveling motor, its proper field of application is apparently to stationary and marine engines. Securing in the latter probably a great economy of space by the use of petroleum fuel.

Ammonia motors invented by Dr. Emile Lamm were run in New Orleans in 1871, and favorably reported upon by a committee, of which Gen. Beauregard was chairman, but these motors were soon abandoned in favor of the hot-water motors, which were found to be, in the language of Gen. Beauregard "*cheaper and less troublesome.*" As hot water cannot compare favorably with steam, no more space will be here devoted to a consideration of ammonia motors.

Gas Motors.

The best type of gas-motor known to the writer is the Connolly. The power was furnished by the vapor of naphtha exploded with admixture of air in a cylinder surrounded by a water-jacket. The water was warmed by the combustion of the naphtha and its circulation around the tank furnished the vapor required by the engine. The cost of fuel was very low and there were many ingenious mechanical devices in the construction of the motor. A serious objection was the necessity for keeping the engine running and out of gear while the motor was standing, so that the

temperature, for the evaporation of the naphtha could be maintained and avoid delays in starting. Twenty of these motors were ordered for street service in Chicago, but after several explosions, the last of which set fire to the car-house, they were abandoned.

Gas, compressed into reservoirs, would avoid some of the objections to naphtha; but would be more expensive.

It has never been seriously proposed to use gas-engines for the operation of rapid-transit lines in New York. There is not sufficient information to condemn them as entirely impracticable, and on the other hand, it would require a very careful investigation before it could be decided that they could be adapted to this service. The writer is not aware that any investigation by competent experts has ever been made to determine whether gas-engines would meet all the requirements of rapid-transit service in great cities, and it would not be well to try experiments on a large scale when other systems known to be successful, and probably quite as economical, can be adopted without risk of failure.

Storage Batteries.

Sanguine expectations of success have been entertained in the use of storage-batteries. The importance of independent motors not subject to derangement by accident, or failure at a central station has long been appreciated, but unfortunately success has not as yet rewarded efforts. In the city of Washington it is said that several hundred thousand dollars have been fruitlessly expended on storage-battery experiments.

As it is not probable that the idea of using storage-batteries for rapid transit in New York has been seriously entertained by any one, it would be useless to waste time in occupying space by the further consideration of this subject.

There are other schemes to which it is scarcely necessary

to refer, as there is no probability that they will be seriously considered, such as Brunel's old atmospheric railway, which has recently been revived under a new name and in a more objectionable form. The choice of motive power must therefore lie between steam, cable, electricity, and compressed air.

Steam.

Steam requires less expenditure for plant than any other system, and taking interest, depreciation, and repairs into consideration is cheaper than any other, air excepted. There is no experiment about steam. We are familiar with the locomotive, and know what it will do and what it will cost. Notwithstanding the absurd claim for electrical railroads running trains at a speed of 100 miles per hour over extended lines of hundreds of miles, it is not probable that prudent investors will soon contribute capital to such projected lines or that for such purposes steam will be superseded.

Where steam must be used to generate electricity with the losses in transmission from the prim mover or the dynamos, from the dynamos to the conductors, and from the conductors to the motors, with the greatly increased cost of plant and of maintenance, it will be found preferable for all rural and transcontinental lines to use steam directly as a source of power, but as the "Herald" says, for underground travel in New York, "steam is, in the opinion of a great majority, out of the question, as passengers would never stand the heat, smoke, and gas."

Cable.

It is conceded that the cable system will not do, as it is both uncertain and dangerous. "The terrible and varying "strain is likely to part the cable and stop the entire traffic "of the line, then there is danger of loose strands of wire

" fouling with the grip, and causing a runaway train, which " may play havoc. Every engine should have its own motor, " and one that is not an experiment, but a tried one that " does its work. The electric motor fills the bill exactly " and nothing else aprroaches it. There is now little diffi- " culty in operating these motors from a central station, and " when the system is used under-ground the few difficulties " will be overcome. The South London under-ground road " is run by the trolley system and gives complete satisfac- " tion."

The above is a quotation from the "Herald" article, and the statements in regard to the cable are by no means overdrawn as experience in Chicago and other cities fully confirms, so that the cable may be excluded, and the only remaining competitors will be the trolley and compressed air.

Electricity.

The trolley does not fulfill the condition that "every engine should have its own motor," if by this is meant the independent motors that the storage-battery was expected to furnish. On the contrary, every motor on the line is tied to the central station, and is as much dependent upon it as the cable lines. Every one is familiar with the facts of the blockades caused by electric storms, of shocks by live wires, of conflagrations caused by crossing telegraph and telephone wires, of heavy fire losses caused by the obstructions to the free use of apparatus, of the destruction of gas and water-pipes by electrolysis, and the poles and wires are tolerated only because regarded as a necessary evil. It is not correct either to assert that the South London underground road has been a success. This is an electric subway or tunnel route, known as the Greathead System. It is a mere toy. It has, as its complete equipment, 36 cars and 14 engines. It carried during the fiscal year of 1891

the insignificant number of 5,161,398 passengers. It earned no dividends. Its total paid-up capital raised by loan and debenture stock was 810,718 pounds for three miles of road, or $1,351,196 per mile. The system is neither efficient nor cheap.

Rapid transit is impossible on any road, or in any locality, where there are numerous stops per mile. On the Third Avenue Railroad the average is 3.06 stops per mile, and the schedule speed, which is a maximum with safety, is only 11.6 miles per hour. To attain an average of 20 miles per hour, there must be few stops, and this requires separate tracks for through and local traffic. To obtain reliable data on which to base estimates of the cost of installation and of operation of an electric road, such as would be required for rapid transit in New York, from South Ferry to the Yonkers' Line, information was sought from officers of the General Electric Co., the problem submitted being: Given a double-track road twenty miles long, with trains similar to present elevated trains, running at one-minute intervals, and 20 miles per hour, or 2 hours for the round trip, how many power stations would be required, where should the stations be located with reference to the termini, what power would be required at stations, and what the cost in detail of the installation? The inquirer was referred to Mr. Baker who had charge of the construction and installation of the Intramural Railroad at the World's Fair, who kindly answered all questions and furnished the information desired.

Based on the figures thus obtained, an estimate was made of the cost of the electrical installation of such a line which gave $8,960,000, or fifteen times as much as with steam locomotives, and five times as great as with compressed air.

In a round trip of two hours, one hundred and twenty trains will have covered 4,800 miles, and the cost of fuel in

performing this work by the different systems was electricity \$575, steam \$384, and compressed air, \$168.

This estimate was fairly made and gave the exact results from the figures furnished, but it seemed excessive, so far as applied to the cost of electrical installation, and the editor of one of the technical magazines submitted the figures to an expert of the General Electric Company who reported that the estimate was excessive, and by basing his calculations on average, and not in maximum resistance, he reduced the cost of installation to \$6,000,000. Even this was three times the cost of compressed air plant, and the operating expenses were double.

These estimates have led to a discussion in the "Street Railway Review" and in the "Street Railway Gazette," and space cannot be occupied here with a repetition of the arguments on either side, but this fact is certain, that both in installation and in operation, compressed air is far more economical than electricity, and other things equal should be entitled to a preference. If other things are not equal, and if the differences are overwhelmingly in favor of compressed air, then air is left without a single competitor. That this is the case can be readily demonstrated.

Compressed Air.

In 1879 the writer was called upon to investigate and report upon five compressed air motors that had been constructed on the plans of Robert Hardie, and run upon the Second Avenue Surface Railroad in New York. The tests were entirely satisfactory, and the report favorable. The consumption of free air per mile-run being less than 300 cubic feet. A motor was then built at the Baldwin works, in Philadelphia, on the plans and under the supervision of Mr. Hardie, and was tested on the Second Avenue Elevated Railroad. It ran from Harlem to South Ferry with a regu-

lar train on schedule time, making 23 stops. It was run by an engineer taken from one of the steam-locomotives who had never before handled the motor. The master mechanic, chief engineer, and several other officers of the road witnessed the test and certified to the results, and these certificates, which are of the strongest character, can be seen by any one interested. The engine not only made the trip to South Ferry but had a reserve of air enough to run it back to the shop. The general manager declined to give a certificate of the result of the tests, and it was suspected that the reason was an apprehension that the certificate might be published in the papers and cause trouble with the directors, who would be compelled by popular clamor to throw away their locomotives and change their system, and they were not ready for it.

On the surface-road the company was willing, it was said, to make a contract to run the road with any company who would equip it with air-motors, but the parties interested had neither capital nor business capacity and nothing was done. A magnificent mechanical success proved a financial failure from the antagonism of vested capital opposing a change of system which involved expense. In Philadelphia the presidents of city railroads refused to consider a proposition to use compressed air on the ground that any car running on the street without horses would frighten teams and cause suits for damages. Public opinion had not then been educated to desire or permit a better system than horse-power.

The field for compressed air has been greatly extended by the discovery in Europe of a process for manufacturing reservoirs without a rivet, joint, or weld, from which leakage of air at any pressure short of rupture is impossible. These reservoirs are tested to 3,500 pounds per square inch without reaching the elastic limit, and are perfectly safe under 2,000

pounds pressure, while it is difficult to make riveted reservoirs tight under 600 pounds. With 2,000 pounds pressure there is no difficulty in providing reservoir capacity sufficient to run a train fifty miles with one charge of air. This may seem absurd to those who are ignorant of the properties and capabilities of air, who have never investigated, or who have not sufficient intelligence, or have too much prejudice to yield to evidence, but conviction will be sure to follow intelligent investigation. It must be expected that the introduction of compressed air will be resisted by those who are interested in the trolley and other systems, but the law of the survival of the fittest must in the end be vindicated, and the sooner the change is made the smaller will be the losses in the transition.

The cost of high pressures is much less than is generally supposed. An 8-ton motor will run 12 miles on 3,600 cubic feet of free air compressed to 500 pounds per square inch, and to start cars at intervals of one minute will require 1,080 horse-power at the compressors, but to increase this pressure to 1,000 pounds would require only 180 horse-power in addition, or one-sixth more, and the whole cost for fuel would be less than one cent per mile-run.

If ammonia engines should be used with the compressors, on the Campbell engine principle, it is not an unreasonable supposition that this fuel cost may be reduced one-half.

I am quite sure that whatever may be the practice of others, you will investigate and decide all questions fairly on their merits. Ignorance is dense and general in regard to compressed air, and full investigation is necessary before a reliable opinion can be reached.

But the solution of the problem of rapid transit in New York does not depend solely upon the motive power to be employed. The question of capacity, and the ability to carry with comfort the number of passengers demanding transpor-

tation is one of vital importance, and one upon which very erroneous ideas have been entertained, even by those who from official position, or by connection with transportation interests, might be supposed to be familiar with the subject. The assertion that beyond certain moderate limits the number of passengers carried per hour cannot be increased by increasing the weight of engines and number of cars when propelled by gravity adhesion engines, and that an increase of speed, so far from increasing the number of passengers per hour, actually and rapidly reduces the number, is received with incredulity and to some appears absurd, yet that such is the fact can be readily demonstrated.

An article by Mr. Lewis Heilprin, in the "Engineering Magazine" of July, 1892, is probably the most practical and intelligent explanation of the requirements for rapid transit in the City of New York, that has been given to the public.

This article recognizes, what others generally have overlooked, viz: the importance of maximum seating capacity per train, and the fact that the maximum carrying capacity per hour is measured by seats per train and trains per hour, passing any given point, and is entirely uninfluenced by the speed. Increased speed enables a smaller number of cars to accommodate a given volume of business, but does not increase the volume itself. On the contrary increase of speed will diminish the volume.

Mr. Heilprin estimates that the demands for transportation in the near future, especially with increased facilities during the busy hours of the day, will require a carrying capacity of 150,000 passengers per hour in one direction. How many tracks of equal capacity to those now in use will this require?

The present five-car trains, with 48 seats per car, have a capacity of 240 per train.

The actual intervals between trains, as determined by

count for one hour on the Third Avenue road at the busiest hour of the day, was 110 seconds, and the seating capacity per hour with this headway is 7,852. If the headway is reduced to ninety seconds the capacity will be increased to 9,600, and if it were possible to average one minute, the maximum seating capacity per hour would be 14,400.

It would appear to require 15 tracks in one direction, or 30 lines of track for both directions, requiring 11 additional double-track lines beyond the capacity of the four lines now in operation. It may be possible, however, to reduce the total number of tracks required by using some of them during certain fixed hours in one direction and during other hours in the opposite direction.

This calculation is moreover based on uniformity of distribution, but the actual distribution at present is far from uniform between the four lines. While the Third Avenue has carried 13,200 in one hour, the Second Avenue has carried 2,304; the Sixth Avenue 5,568, and the Ninth Avenue 3,264. There is apparently no railroad in the world that can equal the Third Avenue, as now operated, in its capacity for accommodation.

The want of facilities cannot be supplied by the construction of more elevated lines, for all available routes appear to have been occupied.

Can the capacity be increased by heavier engines, stronger structures, and longer trains?

Heavy engines with gravity adhesion and increased weight of trains will not give the required relief, as increased weight will increase delays in stopping and starting, and increased length of headway will reduce capacity per hour.

A fair illustration of the capacity of a four-track line, worked with heavy engines of 92,594 pounds, or double the weight of the Third Auenue engines, is found in the Viaduct

line of Berlin. The maximum number of cars per train is 10, the intervals 5 minutes, and the seating capacity of one line in one direction per hour is only 5,760. If the headway could be reduced to 3 minutes, which is considered a possible maximum, the capacity would be increased to 9,600, which is only the capacity of the present light five-car trains on the New York Elevated Railroad with 90-second intervals.

The London tunnel-trains, with heavy engines, carry 6 cars with 3 minute headway, and have a capacity per hour of only 4,320 seats. The London and Northwestern 14 cars, with 4 minute intervals, has capacity per hour of 8,400 seats.

The Boston and Maine 8 cars, of 52 seats each, with 3 minute intervals, has capacity of 8,320 seats.

The Chicago Cable trains, 5 cars of 40 seats, at 2 minute intervals, have capacity per hour of 6,000 seats.

If a standard railroad train of 10 cars, each car carrying 60 passengers, should be dispatched from any city station at 10 minute intervals, the capacity of the line at any speed would be but 6,000 per hour.

A far greater capacity than these would be required to satisfy the transit demands of the city of New York.

It is a mistake to suppose that increased weight of trains admits of higher speed than lighter trains. Of course, transcontinental trains must be heavy, for there are few trains per day with long intervals between stations. With 2½ to 3 stops per mile, as on the New York Elevated, the delays caused by heavy trains would be greatly increased and the capacity reduced, and very good reasons are given for the apparently paradoxical statement of Mr. Heilprin that an increase of speed on a city railroad from 20 miles per hour with 1 minute intervals, if such were possible, to 40 miles per hour, would reduce capacity from 15,000 to 6,000 in consequence of the increased headway required to avoid

collisions and the greater time lost in stopping, starting, and gaining speed.

Even the speed of 20 miles per hour, which would be very moderate upon an ordinary railroad, is quite unattainable upon a city line with frequent stops. Twenty miles per hour would be three minutes to a mile. If there were three stops to a mile and each stop one minute, the whole time would be used and no degree of speed could give a 20-mile average. Rapid transit is possible, therefore, only by providing separate tracks for through and local traffic.

It may be shown that high speed with heavier engines, instead of increasing capacity, as some suppose, would actually reduce it. Fast trains must be kept at a much greater distance apart, and at 40 miles per hour a safe interval between trains would not be less than $2\frac{1}{2}$ minutes, but this interval would pass but 24 trains in an hour, and if of present size the number of seated passengers would be but 5,760.

For the reasons given it does not appear that ordinary locomotives with gravity adhesion can give the requisite capacity without a great multiplication of tracks, and relief from excessively crowded cars is not to be expected unless some plan can be adopted by which a greater seating capacity per train can be secured, with shorter intervals between trains, and as a consequence more trains per hour. The only system that claims to fulfill these conditions is the Meigs; the chief peculiarity of which is a grip adhesion controllable by the engineer and not dependent upon gravity. There is much prejudice against this system in the minds of those who have not given it intelligent and unbiased examination, but those who have, are generally very favorably impressed. Gen. Starke, who examined it for the Massachusetts R. R. Commissioners and subjected it to the severest tests, reported strongly in its favor, and the distinguished engineer and president of the Quaker City Railroad of Philadelphia, Mr. Charles W. Buchholz, having examined

the Meigs system in the interest of New York capitalist, used this language in his report: "I am forced to admit that "after considerable study of the subject, and after long "deliberation, I have been driven from the position of a "thorough sceptic to a believer in the Meigs system within "a limited scope.

"There is no question of the entire practicability of con-"structing the road, and there would be no difficulty in "operating it if locomotives of this new type can be built "that will at all times perform their work with the same "regularity as those now in use."

The only uncertain point in the opinion of Mr. Buchholz seems to have been the ability to construct locomotives that could be depended upon to do the work, but as a full-size locomotive with tender and passenger car were constructed and run for some years on an experimental track at East Cambridge, with a grade of 345 feet to the mile and curves of 50 feet radius, there does not seem to be any good reason for doubt. If one locomotive did actually do its work, any number of locomotives of the same type should perform as well. At all events, there is sufficient merit in the system to warrant a full examination before deciding upon rapid-transit plans in New York, and although the East Cambridge engine was run by steam, yet, if that is objectionable, there can be no serious difficulty in substituting compressed air, for the same volume of air and steam on a piston at the same pressure will give equal power of propulsion.

The "Herald" report was not quite correct in the opinion that there was no necessity for a decision on the question of motive power until the subway approached completion It is possible that the power to be used may have some influence on the form of section to be adopted in construction.

H. Haupt,
Consulting Engineer,
Washington, D. C.

RELATIVE COST OF STEAM, COMPRESSED AIR AND ELECTRICITY FOR THE OPERATION OF RAILROADS.

By Herman Haupt, Consulting Engineer.

There seems to be a general misapprehension in regard to the relative economy of electricity as a motive power for the propulsion of cars upon surface and elevated railroads, as compared with steam and compressed air. It has been proposed to use electricity for the operation of elevated railroads in Chicago and New York, and it was also proposed for an under-ground system for the latter city.

Electricity has apparently been applied with success to the operation of street railways hauling one or two small cars, but the cost of equipping a railroad for hauling heavy trains long distances with stations at short intervals, as compared with steam or compressed air, becomes excessive, and the cost of operation is much greater than with compressed air.

The idea is generally entertained that heavy grades are more easily overcome by electricity, but a moment's reflection ought to satisfy any one that this is a fallacy, for it requires a fixed amount of power to overcome a given resistance, whatever motive power is used.

Having been called upon recently to examine and report upon the relative cost of plants, and of operation for the new lines of elevated railroad proposed to be constructed in New York, the writer sought an introduction to the officers of the General Electric Company, by whom he was courteously received, and who very kindly furnished all the data required for electrical installation.

The problem submitted to them was: "Given a double-track elevated railroad, twenty miles long, with trains similar to present elevated trains, running at one-minute inter-

vals, and twenty miles per hour, or two hours for a round trip; how many power stations would be required for the operation of the line, where should the stations be located with reference to the terminals, what power would be required at stations, and what the cost in detail of the installation?"

The answers, which were based on the actual experience and results of the Intramural Railroad at the World's Fair, were as follows: The cars had two 4-wheeled trucks, and a 150 horse-power electric motor was attached to each axle, making 600 horse-power for each electric motive power car, costing for each car so fitted, $10,000. The trains were made up of one such car and three trailers, and it was stated that the same power would be required to operate the elevated railroad trains. It was also stated that the horse-power at the motors would be less than that at the power stations by 35 per cent., the loss being

From steam-engines to generators	10 per cent.
Transmission along conductors	10 " "
From conductors to car motors	15 " "

As there would be 120 trains on the road at a time, there would probably be 100 using current at once, the balance making stops at stations, and if each train requires 600 horse-power, there would have to be supplied at the motors 60,000 horse-power; and allowing for the losses of 35 per cent. the steam engines at the power-house would have to develop over 92,000 horse-power. The cost of installation at the power-houses was given as $80 per horse-power, made up as follows:

Steam-engines	$20.00
Generators on dynamos	20.00
Boilers	17.00
Piping	3.00
Buildings	10.00
Real estate and incidentals	10.00
Total	$80.00

Chas. H. Davis, in his hand-book of tables for electrical engineers, gives the cost per horse-power at $80 without buildings and real estate, which would increase the above to $100, but $80 was taken as the basis of the estimate.

The power stations were to be two in number, located each five miles from the terminals, so that the current would not have to be transmitted to a greater distance than five miles, the loss being proportional to the distance. The conductors recommended were old iron, or steel rails, as being more economical than copper of equal conductivity. Six lines of these rails being required in the first mile from the power stations in both directions.

It is estimated that the cost of installation, based on the above data, would be as follows:

Rails for conductors.	$250,000
Laying, insulating, and copper connections.	150,000
Outfit for 120 motors, at $10,000 each.	1,200,000
92,000 horse-power at power-houses, $80 each.	7,360,000
Total.	$8,960,000

The writer's original estimate gave the amount as $9,600,-000, but upon reflection it did not seem as if sufficient allowance was made for trains stopping at stations and during that brief interval using no current. He now thinks 20 trains out of 120 a fair allowance. As compared with steam and compressed air plant to perform the same service, the cost would be: 120 steam-locomotives at $5,000 each, $600,-000; 120 compressed air-motors and compressor plant, $1,-800,000. The compressor plant is taken at manufacturers' estimates, and what they are willing to guarantee.

It may be noted that 120 motors would not be sufficient for such a service, as there are always a number of engines in relays, in reserve, and undergoing repairs, but as electric motors cost double what steam and compressed air-engines

do, the comparison would be still more unfavorable to electricity if the number was increased.

The relative cost of fuel for operating is computable as follows:

Elevated steam-locomotives consume about 40 pounds of anthracite coal per train mile, costing, say, \$6 per ton in Chicago and \$4 per ton in New York.

Stationary engines for generating electricity or compressing air, consume about 2½ pounds of bituminous coal per horse-power per hour, costing, say, \$3 per ton in Chicago and \$2.50 per ton in New York.

The compressed-air locomotive tested on the New York Elevated Railroad in 1881, used 1,470 cubic feet of free air per train-mile, which was stored in the motor reservoirs at 600 pounds pressure per square inch. The total quantity of air stored before beginning the trip was 18,400 cubic feet of free air, the reservoir capacity being 460 cubic feet and the pressure 40 atmospheres.

The builders of air-compressing machinery are ready to contract for power plants to do this work, and will guarantee that the consumption of fuel shall not exceed a rate of 20 pounds of bituminous coal per 1,470 cubic feet, compressed to 600 pounds per square inch. This is the equivalent of 20 pounds of coal per train-mile for compressing the air. In addition to this it requires between 4 and 5 pounds of anthracite coal per train-mile to reheat the air as it is used on the motors.

In a round trip of two hours, 120 trains will have covered 4,800 miles; and we shall compare the cost of fuel in performing this amount of work by the different systems.

Electricity—92,000 horse-power for 2 hours at 2½ lbs. per h. p. per hour		230 tons.
Steam—4,800 miles, at 40 lbs. per mile		96 tons.
Compressed air—4,800 miles, at	20 lbs. bituminous coal	48 tons.
	5 lbs. anthracite coal	12 tons.

At a cost of

Electricity, 230 tons . . . . at	$3.00 = $690.00 in Chicago. 2.50 = 575.00 in New York.	
Steam, 96 tons . . . . at	6.00 = 576.00 in Chicago. 4.00 = 384.00 in New York.	
Compressed air. .	48 tons at $3.00 = $144.00 12 tons at 6.00 = 72.00	= $216.00 in Chicago.
Compressed air. .	48 tons at 2.50 = 120.00 12 tons at 4.00 = 48.00	= 168.00 in New York.

The writer was much surprised at the result, for although he expected to find that electricity was much more costly than steam or compressed air, from previous investigations, he was not prepared for such a difference; and after reflection he began to doubt the correctness of the figures furnished. It does not seem that it should require 600 horse-power to move an elevated train, although he is positive the statement was made by the officials of the General Electric Company. The steam locomotives of the Manhattan Railway weigh about 48,000 pounds, the cylinders are 12 by 16 and the drivers 42 inches in diameter. As the steam-pressure carried does not exceed 140 pounds per square inch, the horse-power probably does not exceed 250, but he is also aware that these engines are worked to their full capacity in moving trains from station to station. It is not a case of urging the trains into speed and then running at an even pace, but a case of continual acceleration until the next station is reached, and this is frequently carried so far that the brake-valve is opened before the throttle is closed, to avail of even the short interval between opening the valve and the brakes taking effect to accelerate the speed and gain time.* Profiting by the experience of the Manhattan Company, Chicago, and other places have built heavier structures, which admits the use of heavier engines; those on the Lake Street Railroad, for instance, weighing as much as 60,000 pounds. It is safe to say, therefore, that 300 horse-

*The Eames vacuum brake is used on these trains.

power per train would be a fair allowance, although the writer cannot understand why there should have been 600 horse-power on the Intramural Railroad, unless it is that an electric motor works best when not taxed to its full capacity, or unless 600 horse-power at the electric motor only means 300 horse-power at the rail. This seems likely, as an excess of power would slip the wheels.

After a discussion of the subject with the editor of one of the technical magazines, who also doubted the accuracy of the figures, they were submitted to a prominent electrician of the General Electric Company for revision. That gentleman reported that the estimate was excessive, inasmuch as it had been based on maximum instead of average resistances. He returned a revised estimate, based on average resistances, with an allowance of 9 per cent. for fluctuations, which gives 42,000 horse-power as all that was necessary at the power stations, and $6,000,000 as the total cost of installation. As 42,000 horse-power at $80 per horse-power is only $3,600,000, the writer rather underestimated the cost of conductors, laying, etc.

After deducting 35 per cent. for losses, there will only be 27,300 horse-power available at the motors, or say an average of 273 horse-power per train using current at once. It is difficult to understand how the maximum power can be 600, the average 273 and the fluctuation 9 per cent.; but accepting the revised estimate of 42,000 horse-power, and six millions as the cost of installation, it will be seen that the latter is still many times greater than for steam or compressed air.

The relative cost of fuel for operating in two hours as revised would be:

	In Chicago.	*In New York.*
Electricity (105 tons).	$315.00	$262.50
Steam	576.00	384.00
Compressed air	216.00	168.00

The fuel used for operating the Intramural road was oil, and the writer is credibly informed that the average consumption during the six months of the Exposition was at the rate of an equivalent of 50 pounds of coal per train-mile. This would give 120 tons for 4,800 miles, which is rather more than above.

The interest on the cost of installation is another item of the operating expenses affected, and ought to be considered in conjunction with the cost of fuel. It is for two hours at 6 per cent. as follows, based on the supposition that the road is operated twenty-four hours per day :

Electricity	$6,000,000.	Int.	$82.20 for two hours.
Steam	600,000.	Int.	8.22 for two hours.
Compressed air.	1,800,000.	Int.	24.66 for two hours.

Making the combined expense for fuel and interest—

	In Chicago.	*In New York.*
Electricity	$397.20	$344.75
Steam	584.22	392.22
Compressed air.	240.66	192.66

Compressed air cannot be considered as an experiment, although the evidence that comes of long-continued use is wanting. The writer and others can testify to the admirable results obtained from the street-motor trials in New York. They answered every requirement of the service, proved to be economical, and no valid objection was ever raised against them. They could and did carry storage of air sufficient for trips of ten miles, so that trips of eight miles were well within their capacity. The capacity of the reservoirs was equivalent to 4,266 cubic feet of free air, and they used 290 cubic feet, equal to 22 pounds weight of air per mile on an average. The Mekarski system is in successful operation in France, although they use over 24 pounds

of air per mile,* and are clumsy in general design and appearance.

In 1881 a compressed-air locomotive was designed by Robert Hardie, and constructed at the Baldwin Locomotive Works, Philadelphia, under his supervision. It was tested the same year on the Manhattan Elevated Railway, with marvelous results. The tests were witnessed by a number of the officers of the road and others, who were enthusiastic in its praise, and some of whom gave written certificates of the performance. They are as follows:

John A. Wallace, engineer, who operated the engine on the trial trips.

E. B. Wetmore, who was train-master when the trials were made. He has since been superintendent and master mechanic of the Suburban Elevated, New York, and of the Chicago & South Side Rapid Transit Company.

Wm. S. Hughes, who was foreman of repair shops on the Manhattan, when the trials were made, and who is now master mechanic of a division of the New York and New England railroad, at Providence, R. I.

Col. R. I. Sloan, formerly chief engineer of the Manhattan. Since chief engineer of the Chicago & South Side Rapid Transit, and now chief engineer of the Lake Street Elevated railroad.

Chas. T. Parry, of the firm of Burnham, Parry, Williams & Company, Baldwin Locomotive Works, Philadelphia, and others.

Too much space would be required to publish these certificates in full, but they all express appreciation and approval in strong terms. The question is naturally asked

* A pamphlet recently published by the American Mekarski Company states that on one of the roads operated, 1,985,000 pounds of air was used to operate 82,250 miles, which gave "$\frac{1985000}{82250} = 22\frac{1}{2}$ pounds per mile." This was an error of division.

why was the system not adopted if the tests were so satisfactory and there were no neutralizing disadvantages.

It may be said briefly that the main causes of its abandonment were bad management, incapacity, and lack of financial ability on one hand, and prejudice, incredulity, and indifference on the other.

The company organized to develop the system was composed of men who had no financial standing, and were incapable of surmounting the usual obstacles which all pioneers have to meet. The principal of these objections was the fear that damages from scaring horses would be heavy, which has since proved to be groundless. The company had not the financial ability te equip and operate the first line of road, and no railroad company would adopt it without such a demonstration, although a magnificent success mechanically.

The Elevated Railroad Company not only declined to introduce it on their road, but the management declined even to give a statement of facts as to its operation on the road. It was strongly suspected that the reason for this was the fear that publicity given to such an official statement would bring the pressure of popular demand for its adoption, involving the expense of re-equipping the road with motive power; though a change would obviously be a public benefit; besides effecting a great saving in the operating expenses. Of the latter fact, however, the management is still ignorant. It is a fact, strange as it may seem, that no official test or investigation was ever made to ascertain the cost of operation, which fact implies that no such information was wanted. There is no lack of testimony, however, to show that the experimental engine fulfilled all the conditions and answered all the requirements of the tests so far as they went; in hauling trains over the road on schedule time; in making all the regular station stops to

pick up and set down passengers; in ease of handling and smoothness of operation, and in freedom from noise of exhaust, gas, cinders, &c., as well as the fact that the car-brake equipment was operated from the engine as usual; that the length, breadth and height was the same as the steam-engines, that weight was from 6,000 to 8,000 pounds less than the steam-locomotives recently built for the same road; that they can be recharged as quickly as the steam-locomotives take water; that the cost of fuel for operation is less than 50 per cent. of that of the steam-locomotives; and that there never was any fault found or objections raised against it whatever. All these facts can be proved to the satisfaction of any one caring to investigate. It is safe to conclude, therefore, that the only difficulty was the one stated above.

The recent report of the railroad commissioners of Massachusetts, presented February 7, 1894, in referring to the trolley system, states that during the year there has been "an increase of 214 miles of electric road" and "over $25,000,000 of capital invested." The report also says, "It can and should be said without hesitation or qualification that the electric system has not shown or indicated any such margin of profit as to justify the expectation of more than ordinary and moderate returns on money legitimately invested in it. The idea which seems to have obtained some currency that the electric railway system is a bonanza of rare and inexhaustible weath is clearly a delusion, and has doubtless proved to some a snare. The absolute cost and expensiveness of the system, under the most conservative, able, and honest management are sufficient to tax its earning capacity to its full limit. There is no margin for inflated or fictitious capitalization. It presents no safe or inviting field for speculative enterprise or manipulation, unless it be to the unscrupulous operators of an inside ring, who are willing to practice on the crudulity of a misinformed

public. Whenever there is reason to believe that water has been, or is about to be injected into the stock or bonds of an electric railway company, the only safe course is to let its securities severely alone."

In a recent letter from the electrical editor of a standard technical magazine, it is conceded that electricity cannot compete with compressed air for street motor purposes; that the storage-battery is an *ignis fatuus*, and that expenditures in this direction will probably be discontinued; and that long interurban lines like those projected between New York and Philadelphia, St. Louis and Chicago, and Baltimore and Washington, are wild and visionary schemes.

Where steam can be used directly in a motor, electricity generated by steam cannot be employed economically for car propulsion. This is not so with compressed air, as the reheating on the motor almost wholly restores the losses by compression and transmission. The great field for electricity is electric lighting, and perhaps electric heating. It may also be advantageously used for transmitting power long distances from water falls, although compressed air may here again be a successful competitor; but for the propulsion of cars and trains on railroads, it must eventually give way to compressed air.

Gas-motors have exploded and burned up. Cable lines can only be operated on long lines of straight track with advantage, and then only when there is a "magnificent business." Steam is intolerable, carbonic acid gas and ammonia are impracticable, and life is too short to wait for horses. It would seem, therefore, as if compressed air, which is growing in popular favor, remains head and shoulders above all its competitors; and the writer ventures the prediction that in a few years it will be in universal use for the operation of street railways. Why it has lain beneath and so near the surface so long is past the writer's comprehension.

WASHINGTON, D. C., *March* 23, 1894.

RELATIVE COST OF STEAM AND ELECTRICITY FOR THE OPERATION OF RAILWAYS.

By W. E. Baker, General Manager, Columbian Intramural Railway.

Having been shown the preceding article, in which the relative merits of compressed air, steam, and electricity for elevated railroads are discussed, I gladly avail myself of the opportunity to reply.

While this article bears evidence of having been prepared with great care, there is in it the assumption of a condition in regard to the rate of speed which, in the absence of an explanation, is misleading and leads to manifest error in the conclusions drawn.

As a result of practical experience with the only elevated electric railway operated on a large scale, I beg to submit the following, which I trust will be of interest to your readers :

In the article referred to, while the writer does not himself take the position that he is fully cognizant of all the facts connected with the operation of an electric elevated road, the unfairness of the comparison from which his deductions are made, beeomes apparent when the problem thus submitted is carefully examined, and particularly the clause referring to the speed of the train, which is to be 20 miles an hour.

The writer then proceeds to compare the cost of operating an electric road with trains making an average speed of 20 miles an hour with the cost of operating a steam-road under present conditions, where the average speed is about 12 miles an hour, slightly less than this in New York and slightly more in Chicago, the stations in New York being about

1,725 feet apart and in Chicago about 2,000 feet, and it is plainly unfair to make the comparison on this basis. The comparison should be made either on the basis of 20 or 12 miles per hour under the different methods of operation. As all the elevated roads which have been operated, or are now being operated, including both the steam and electric roads, have been operated at an average speed of about 12 miles an hour, it would seem better to make the comparison on this basis, as, if we attempt to compare the operation of roads at the speed of 20 miles an hour, we must assume the conditions for both cases.

As a matter of fact it is practically, and at any rate commercially, impossible to operate an elevated road with trains of five cars and stations about one-third of a mile apart, at an average speed of 20 miles per hour, especially with the present conditions and limitations of brake mechanism, as a very short calculation will suffice to show. At a speed of 12 miles per hour, and with stations one-third of a mile apart, it would be necessary to make three stops in a mile, averaging 17 seconds. This would leave for the three runs to be made in a mile 249 seconds, or an average of 83 seconds for each run, 30 seconds of which would be used in retardation; leaving 53 seconds only in which to make the acceleration from a state of rest to a speed of about 25 miles per hour. At 20 miles per hour or 180 seconds to the mile, and with three stops, we have 129 seconds in which to make the three runs, or 43 seconds to each run. If we allow, as above, 30 seconds only in which to make the retardation, which is not enough, as we will have to retard from a much higher maximum speed, still we have only 13 seconds left in which to accelerate to a speed of, say 40 miles per hour, and this is plainly impossible, although the electric operation of trains will approximate this much nearer than steam has ever been able to do.

The attempt (in the article referred to) to make the comparison between steam trains operating at the rate of 12 miles per hour and electric trains at 20 miles per hour, is the basis of the errors throughout the article. A calculation, which it is not necessary to enter into, will show that to make an approximation to the average speed of 20 miles an hour 600 horse-power will be found not sufficient to do the work; notwithstanding the author of the article under consideration expresses surprise that this amount of energy should be required to operate an electric train at a speed of 20 miles per hour. When the speed of an electric train is reduced to that assumed for the steam train, 300 horse-power will be found abundantly sufficient. The horse-power of motors, for the purpose of comparison, should therefore be taken at 300 instead of 600, which will reduce the cost of the motor outfits to $6,000 each instead of $10,000.

Actual experience of the Intramural road, based on twelve days' accurate readings and forty-six separate observations, shows that the average horse-power consumed per train was 42 horse-power. As the stations on this road were only 1,590 feet apart, as compared with the distances of 1,725 feet and 2,000 feet above referred to; and as the road was further complicated by 25 per cent. of curvature, which necessitated cutting down the speed of the trains in many cases after they had expended the power necessary to reach the maximum speed; and as the average speed under these conditions on the Intramural road of a round trip of six and one-fourth miles was 10 miles per hour, the horse-power used there per train would be quite a sufficient amount for a speed of from one to two miles an hour more with stations father apart and with straight track. The accelerations secured on the Intramural road were superior to those obtained on any elevated road now being operated by steam;

and it is no doubt true that no locomotives at present being operated on elevated roads, and light enough to have been used safely on the Intramural structure, could have made the speed on that road which was made by the motor cars.

Therefore, instead of assuming that it will require 600 horse-power to a train in the station, it is true only if the trains are to make 20 miles per hour, and not true as a basis of comparison. We know on the basis of the facts secured in actual practice, 50 horse-power average per train is sufficient, but to allow for the extra car in the train and for surplus power we will allow 75 horse-power as a basis of present comparison.

It must be remembered that this horse-power was measured at the station, and that no allowance need be made for loss in conductors or motors.

The writer of the article makes an allowance of 20 trains out of 120 as the number stopping at stations and during that brief interval using no current. When it is remembered that it takes about 87 seconds from the starting of a train from one station to the starting of the same train at the subsequent station, and of this 87 seconds, 17 seconds are spent at the station and 32 seconds are spent with the power cut off and brake applied, being over 50 per cent. of the time spent during the total run, it will be seen that instead of 20 trains using no current, a proper allowance out of the 120 would be about 70 trains.

It will also be noticed that it has been assumed that 120 trains would make a round trip, giving intervals of one minute.

In this case again the difference in rate of speed has been neglected ; as a matter of fact it would take 210 steam-trains to do this service, and assuming that the electric-trains would make the same speed, 200 electric-trains, for the reason that the electric-train does not have to stop as the steam-train

does for the purpose of raking ashes, building up fires, etc., which could not be less for each steam-train in a round trip than ten minutes. The cost of installation, based, therefore, on the above data would be about as follows:

Conductors and feeder rails	$100,000 00
Laying insulators and connections	50,000 00
200 motor equipments @ $6,000 each	1,200,000 00
15,000 horse-power @ $80.00	1,200,000 00
Total	$2,550,000 00

But this is not all; comparing the locomotives and their effect on the track and structure with that of the motor cars, the saving in the construction will amount to at least 25 per cent. of the cost for the steam road. This will be about $40,000 per mile, or 20 miles at $40,000—$8,000,000.00. But this is not all; it is only fair to compare the two systems completely and not fair to compare the light afforded passengers by smoky kerosene lamps with the brilliant light obtained on an electric road. The only light approximating the electric light is the most improved system of gas-lighting for cars, which would cost about $250 per car, as against about $40 per car to install electric lights, effecting a further saving on 1,000 cars of $210,000; and without referring to the saving of lighting stations and the coaling of water stations, we have as the investment to be compared with the steam a total of $1,540,000, as compared with 210 compound steam-locomotives at $6,000 each—$1,260,000.

Now, to make a comparison of the relative cost of fuel: We have, in a round trip of two hours, 210 trains covering about 8,000 miles; and for electricity, 15,000 horse-power for two hours at 4 lbs. per horse-power hour=60 tons. Steam, 8,000 miles, at 40 lbs. per mile=160 tons. As anthracite is used on the steam-trains, the price still further

emphasizes the difference in operating expenses, which would be for :

Electricity, 60 tons, at $2.50		$150 00
Steam, 160 tons, at	$4.00, New York	640 00
	6.00, Chicago	960 00

It will be seen that under this estimate the difference between the cost of construction of the two systems is so small that it is unnecessary to carry the discussion further, as the assumption of the different rate of speed vitiates throughout the former comparison.

The above statement of saving refers to fuel only—there are other items. The saving of wages on the two hours of a full schedule would amount to $240 in faver of the electric road.

The writer knows nothing about the reliability of the figures given in reference to compressed air, as no experiment has been carried on in this direction on a large enough scale to demonstrate its availability, to say nothing of the expense.

One of the common errors in regard to the electric-road is the endeavor to assume that an electric-road is to do much more work, in a much smoother and pleasanter manner, than the steam-road, and still at less expense. In one of the technical magazines a statement was recently made that a locomotive generates power at a far smaller first cost than any stationary steam-plant, on account of the stationary plant costing from five to ten times as much per horse-power as the cost of a locomotive per horse-power. This statement, while correct in itself, neglects the underlying factors of the operation of an electric-road where the steam-plant would certainly not be over 20 per cent. of the total maximum power required to operate the trains. In the same article referred to, the conclusion is drawn that "Very small power units can certainly be operated more economically by distributing the power electrically from a central station. With large power units it is more economical to generate the power on the spot, just

where the dividing line is to be drawn will depend upon the circumstances in each particular case." This statement ingeniously hides the truth. It is not the size of the power units which renders it more economical to generate the power electrically, but the number. Having a given amount of power to generate, it can be distributed more economically by the use of electric transmission when the units are smaller in size. Bearing in mind that the economy of the motive power is not the only reason for the application of electricity on elevated railways, that the saving in dust, noise, gas and other so-called sentimental reasons must also have great weight, it becomes evident that it only requires a careful, thorough and scientific investigation of the subject to enable one to predict that the time is already come for the operation of elevated railways by electric power.

RELATIVE COST OF STEAM, COMPRESSED AIR, AND ELECTRICITY FOR THE OPERATION OF RAILROADS.

By General H. Haupt, C. E.

I have received a copy of the "Street Railway Review" for April, and have read with much interest and some surprise the criticism of my article by General Manager W. E. Baker of the Intramural Railway. When I was consulted professionally in reference to the plans of construction and operation of the proposed new rapid-transit lines in New York city the question of motive power came up for consideration. There were good reasons for believing that cable was not suitable, but it was thought that either electricity or compressed air might be advantageously substituted for steam.

I happened to be well-posted in regard to what had been accomplished with compressed air, and had sufficient data at hand to guide me in forming my conclusions relative thereto, but had to obtain from others most of my information regarding electricity. I, therefore, sought what may be considered the chief source of light on the subject, the General Electric Company, being favored with a personal introduction to Capt. Eugene Griffin, the general manager. That gentleman received me courteously, and having stated to him the object of my visit, he requested me to await the arrival of Mr. W. E. Baker, who was familiar with every detail from his experience in connection with the Intramural Railway, and who could furnish reliable facts and figures. Mr. Baker met me by appointment three days later at the office of Mr. Henry Belden, New York city, and in the pres-

ence of that gentleman made answer to written questions that were submitted to him, which answers were noted at the time, and furnished the data for the comparative estimate subsequently made. There was no disposition to present any other than a perfectly fair and impartial estimate, and if the comparison was unfavorable to electricity it was simply because the figures, which were not expected to lie, gave that result.

I felt under great obligations to Mr. Baker, and do yet, for the valuable information furnished, and I am naturally surprised at some of the criticisms in his article, as the gentleman seems to have forgotten the conditions of the problem presented to him.

It must be remembered that the information sought was in connection with rapid transit in New York city. That it was proposed to construct two four-track elevated roads—one on each side of the city. That on each of these roads two of the tracks were to be used for rapid transit, with an average speed of 20 miles an hour, and few stops; and the others for local travel, low-average speed, and many stops. It was scarcely necessary to enter into an argument to prove the self-evident proposition that 20 miles an hour, with three stops per mile, was impracticable, and the chief force of the article in question is directed against this assumed and purely imaginary condition.

If Mr. Baker will reflect he must perceive that the cost of equipping and operating a line of road, where the stations are far enough apart to admit of an average speed of 20 miles an hour, will be less than where they are so close as to limit the speed to 12 miles an hour, hence he cannot consistently complain that the comparison was unfair. It is surprising that he should have overlooked this fact, as well as have forgotten the conditions of the problem presented and discussed. He seemed to understand it during our inter-

view in Mr. Belden's office, when he furnished the data referred to. He then did state in the presence of Mr. Belden that "the same power would be required to operate Manhattan trains as was used at the Intramural, which was 600 horse-power, and the cost of equipping each train would be $10,000." He also stated that "the same power would operate the proposed new line." Now he states that careful tests made in the Intramural power-house gave 42 horse-power per train. Allowing for the 35 per cent. loss between power-house and trains, this leaves only 27 horse-power per train. Yet he allows "75 horse-power as a basis of present comparison." I have information from a reliable source that indicator and dynamometer tests made on the Manhattan with an 11x16 inch cylinder engine gave an average of 185 horse-power for all the time the engine was under steam, which I have reason to believe is considerably more than 50 per cent. of the total time of the trip. Here again Mr. Baker seems to be badly mixed, for in one part of his article he gives the average time between stations as 100 seconds—53 under steam, 30 coming to rest, and 17 standing in station. In another part he give it as 87 seconds—38 under steam, 32 coming to rest, and 17 standing in station. This was for the purpose of showing that my allowance of 20 trains out of 120, "using no current," was not sufficient. Considering that his figures tally so badly, and that my allowance was made for a road with long intervals between stations, it is probably nearer the truth than he tries to show, and, anyhow, it only affects my original estimate, which was already subjected to revision by the General Electric Company.

It is strange, in view of all the facts presented and after the statements made by Mr. Baker during our New York interview, that now, as if the subject were new to him, he should profess to believe that I intended the proposed line to be operated at 20 miles per hour with three stops per mile; and

and with this as a text write a two-page article. How can he reconcile his statements then made with the following in his article? "A calculation, which it is not necessary to enter into, will show that to make an approximation to the average speed of 20 miles an hour, 600 horse-power will be found not sufficient to do the work." Of course not, and yet further on we read, "600 horse-power" * * * "is true only if the trains are to make 20 miles an hour," as if remembering his statements at the New York interview.

Being anxious to get at the facts and the truth, and to eliminate all possible errors and misunderstandings, my original estimate deduced from Mr. Baker's figures was submitted, as stated in my article, to the General Electric Company for revision. They placed the matter in the hands of one of their experts (Mr. Blood, if I remember correctly) who cut down the horse-power over 50 per cent. and put the cost of installation at 6,000,000 dollars. There could have been no misunderstanding on his part as to the trains making three stops per mile, for he did not enter into any calculation to show that "600 horse-power would not be sufficient," but stated that my estimate was "excessive," being based on maximum, instead of average resistances. I accepted his explanation, and his revised estimate of 42,000 horse-power and 6,000,000 dollars; but in view of the self-evident fact that it costs less to equip and operate a line of road with stations at long intervals than one with stations at short intervals, it is very much at variance with the final estimate given in Mr. Baker's article of 15,000 horse-power and 2,550,000 dollars, on the supposition that stations would average three per mile.

There are some who believe that the resistance of trains is proportional to the cube of the speed. This is contrary to all experience and very far indeed from the truth. I can

only advise those holding such belief to get better posted before committing themselves to such rash statements.

One thing appears self evident, that a given amount of power will overcome the same resistance, whether the agent be steam, compressed air, electricity, or any other power, notwithstanding Mr. Baker's assertion that "the accelerations secured on the Intramural were superior to those obtained on any elevated road now being operated by steam." If such was the case, it could only have been because of the 600 horse-power with which the trains were equipped, and as seen from the ground there was a frightful amount of "sparking" as the trains started.

Mr. Baker goes on to say that 210 trains would be required instead of 120 to operate the proposed road. This is possibly so. I stated 120 trains would be in operation at one time, making 4,800 miles in two hours, on the assumption that they were one minute apart, and making an average speed of 20 miles an hour. This is probably closer than they could be run in practice, and was intended as an extreme case for purposes of safe calculation. Mr. Baker evidently overlooked my statement that, "It may be noted that 120 motors would not be sufficient for such a service, as there are always a number of engines in relays, in reserve, and undergoing repairs." By what stretch of imagination does he manage to get all the 210 trains running at once, under the above conditions, so as to cover 8,000 miles in two hours? Yet he uses this as a basis for figuring the coal consumption of the steam-engines. A revision of his figures will show him that I put the number of miles correctly at 4,800 in two hours.

Following this is an assertion that 8,000,000 dollars would be saved in the construction of the road. This must be a typographical error for 20x40,000=$800,000. The wisdom, or even possibility, of saving this amount is doubtful, in a

structure that is to last for all time. The cost of maintaining the roadway and track of the Intramural during the six months of the Fair was $4,281.28. This seems a good deal for a new track and roadway, and is doubtless due to the flimsy construction which he advocates.

The subject of compressed air is dismissed with the remark, " No experiment has been carried on in this direction on a large enough scale to demonstrate its availability, to say nothing of the expense."

If one air-motor accomplished all that was stated in my article, it is fair to assume that any number could be built like it, and it is even fair to assume that it may be improved upon. To prove that the motor referred to did accomplish all that was stated, the most unexceptionable testimonials can be exhibited. The record of air consumption furnishes all necessary data as to expense of operation, and parties are ready to quote prices for the equipment of motors and air-compressing plant. Good reasons have already been given why compressed air has not come more into use, and why the above successes were not followed up. To these I would add, that millions of invested capital usually block the way effectually against the introduction of improvements that will threaten dividends, even with a prospect of increased dividends in the near future, a change that requires present expenditures, is resisted. The Traction Company of Philadelphia, killed the elevated road there. The West End Company in Boston did the same; Tammany and Manhattan have closed New York against rapid transit efforts. Is it necessary to explain further why compressed air has not been universally adopted? Everywhere somebody's interests have placed obstructions on the track to block the wheels of progress.

HERMAN HAUPT, C. E.

WASHINGTON, D. C., *May* 5, 1894.

[Railroad Gazette, Friday, July 27, 1894.]

ELECTRIC CARS TO USE PINTSCH GAS.

The Columbus Central Railway Company, of Columbus, Ohio, has closed a contract for the construction of Pintsch works to equip and light its street-cars with this light. This is an electric trolley road and the Pintsch light is used because of its more steady and reliable illumination, and it is estimated will cost but half as much as electric light from the power current.